1.1 Potential Actions and Decisions Regarding the Proposed Repository

This EIS analyzes a *Proposed Action* to construct, operate and monitor, and eventually close a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain. The EIS also analyzes a *No-Action Alternative,* under which DOE would not build a repository at the Yucca Mountain site, and spent nuclear fuel and high-level radioactive waste would remain at 72 commercial and 5 DOE sites across the United States. The No-Action Alternative is included in the EIS to provide a basis for comparison with the Proposed Action. DOE has developed the information about the potential environmental impacts that could result from either the Proposed Action or the No-Action Alternative for the Secretary of Energy's consideration, along with other factors required by the NWPA, in making a determination on whether to recommend Yucca Mountain as the site of this Nation's first monitored geologic repository for spent nuclear fuel and high-level radioactive waste. In making that determination, the Secretary would consider not only the potential environmental impacts identified in this EIS, but also other factors as provided in the NWPA.

PROPOSED REPOSITORY

DOE has used the term *proposed repository* as a convenience to indicate the relationship of a Yucca Mountain Repository to the Proposed Action of this EIS. DOE could not pursue the use of Yucca Mountain for a repository unless the Secretary of Energy decided to recommend approval of the site to the President and a Presidential site designation became effective. At that time, DOE would submit a License Application to the Nuclear Regulatory Commission seeking authorization to construct a repository at Yucca Mountain.

As part of the Proposed Action, which DOE has identified as its preferred *alternative,* the EIS analyzes the potential impacts of transporting spent nuclear fuel and high-level radioactive waste to the Yucca Mountain site from 77 sites across the United States. This analysis includes information on such matters as the impacts of rail and truck transportation nationally and in Nevada, as well as impacts in Nevada of alternative corridors for a branch rail line, routes for heavy-haul trucks, and alternative and associated *intermodal (rail-to-truck) transfer stations*.

DOE believes that the EIS provides the environmental *impact* information necessary to make certain broad transportation-related decisions, namely the choice of a national mode of transportation outside Nevada (mostly rail or mostly legal-weight truck), the choice among alternative transportation modes in Nevada (mostly rail, mostly legal-weight truck, or *heavy-haul truck* with use of an associated intermodal transfer station), and the choice among alternative rail corridors or heavy-haul truck routes with use of an associated intermodal transfer station in Nevada.

DOE has identified mostly rail as its preferred mode of transportation, both nationally and in the State of Nevada. At this time, the Department has not identified a preference among the five potential rail corridors in Nevada.

If the Yucca Mountain site was approved, DOE would issue at some future date a Record of Decision to select a mode of transportation. If, for example, mostly rail was selected (both nationally and in Nevada), DOE would then identify a preference for one of the rail *corridors* in consultation with affected *stakeholders,* particularly the State of Nevada. In the example, DOE would announce a preferred corridor in the *Federal Register* and other media. No sooner than 30 days after the announcement of a preference, DOE would publish its selection of a rail corridor in a *Record of Decision*. A similar process would occur in the event that DOE selected heavy-haul truck as its mode of transportation in the State of Nevada. Other transportation decisions, such as the selection of a specific rail *alignment* within a

corridor, would require additional field surveys, State and local government and Native American tribal consultations, environmental and engineering analyses, and *National Environmental Policy Act* reviews.

1.2 Radioactive Materials Considered for Disposal in a Monitored Geologic Repository

Commercial nuclear powerplants, which supply approximately 20 percent of the Nation's electricity, produce spent nuclear fuel. In addition, DOE manages a complex of large government-owned facilities that formerly produced nuclear weapons materials, and in doing so produced spent nuclear fuel and high-level radioactive waste. DOE also operates research reactors that produce spent nuclear fuel and processing facilities that produce high-level radioactive waste.

The following discussion describes spent nuclear fuel and high-level radioactive waste, including *mixed-oxide fuel* (a mixture of uranium oxide and plutonium oxide that could be used to power commercial nuclear reactors) and immobilized plutonium forms. The discussion also identifies other waste forms, particularly Greater-Than-Class-C wastes and Special-Performance-Assessment-Required wastes, that are currently classified as *low-level radioactive* wastes but that could require disposal in a monitored geologic repository.

1.2.1 GENERATION OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

The material used to power commercial nuclear reactors typically consists of cylindrical fuel pellets made of uranium oxide. Fuel pellets are placed in tubes that are ordinarily about 3.7 meters (12 feet) long and 0.64 centimeter (0.25 inch) in diameter. Sealed tubes with fuel pellets inside them are called fuel rods (Appendix A). Fuel rods are arranged in bundles called fuel assemblies (see Figure 1-2), which are placed in a *reactor*.

In the reactor, neutrons from the fuel strike other uranium atoms, causing them to split into parts, and producing heat, radioactive *fission products,* and more free neutrons. This splitting of atoms is a form of nuclear reaction called *fission*. The neutrons produced by the fission process sustain the nuclear reaction by striking other uranium atoms in the fuel pellets, causing additional atoms to split. Control of the configuration and machinery associated with the fuel assemblies provides control of the rate at which fission occurs and, consequently, the amount of heat produced.

In a commercial power reactor, the heat that fission produces is used to convert water to steam. The steam turns turbine generators to produce electric energy. The reactors that power many naval vessels use the steam primarily to turn turbines to provide ship propulsion. Some research reactors also use the steam produced to generate electricity.

After a period in operation, enough of the fissile uranium atoms have undergone fission that the fuel is said to be "spent"; some of these spent nuclear fuel assemblies must be replaced with fresh fuel for operation to continue. During replacement, fresh fuel is placed in the reactor and spent fuel is placed in a pool of water. In commercial reactors, typical fuel cycles run 18 to 24 months, after which 25 to 50 percent of the spent nuclear fuel is replaced.

Nuclear reactor operators initially store spent nuclear fuel under water in spent fuel pools because of high levels of *radioactivity* and heat from *decay* of radionuclides. When the fuel has cooled and decayed sufficiently, operators can use two storage options: (1) continued in-pool storage or (2) above-ground *dry storage* in an independent installation. Thirty-three sites have existing or planned independent above-ground dry storage facilities. Dry storage includes the storage of spent nuclear fuel at reactor sites in approved storage casks.

Beginning in 1944, the United States operated reactors to produce materials such as plutonium for nuclear weapons. All of these reactors have been shut down for several years. When defense plutonium production reactors were operating, they used a controlled fission process to irradiate nuclear fuel and generate plutonium. DOE used chemical processes (called *reprocessing*) to extract plutonium and other materials from spent nuclear fuel for defense purposes. One of the chemical byproducts remaining after reprocessing is high-level radioactive waste. The reprocessing of limited quantities of naval reactor fuels and some commercial reactor fuels, DOE test reactor fuels, and university research reactor fuels has also produced high-level radioactive waste.

Concerns about safety and environmental hazards contributed to DOE decisions to shut down parts of the weapons production complex in the 1980s. The shutdown, which became permanent due primarily to the reduced need for weapons materials at the end of the Cold War, included both production reactors and spent fuel reprocessing facilities. As a result, not all *DOE spent nuclear fuel* was reprocessed. Some of this fuel is now stored at DOE sites.

1.2.2 SPENT NUCLEAR FUEL

Spent nuclear fuel consists of nuclear fuel that has been withdrawn from a nuclear reactor following *irradiation,* provided that the constituent elements of the fuel have not been separated by reprocessing. *Commercial spent nuclear fuel* comes from nuclear reactors operated to produce electric power for domestic use. DOE manages spent nuclear fuel from DOE defense production reactors, U.S. naval reactors, and DOE test and experimental reactors, as well as fuel from university research reactors, commercial reactor fuel acquired by DOE for research and development, and fuel from foreign research reactors. Most nuclear fuel is encased in highly *corrosion-resistant cladding* before being placed in a reactor. The fuel remains in the cladding after it is irradiated and withdrawn as spent nuclear fuel. The purpose of the cladding is to protect the fuel in operating conditions associated with a reactor. Cladding, if it is not damaged or corroded, has the capability to isolate the spent nuclear fuel and delay the release of radionuclides to the environment for long periods.

Spent nuclear fuel is intensely radioactive in comparison to nonirradiated fuel and would be the primary source of radioactivity and heat generation in the proposed repository.

1.2.2.1 Commercial Spent Nuclear Fuel

Commercial spent nuclear fuel typically consists of uranium oxide fuel (which also contains actinides, fission products, and other materials), the cladding that contains the fuel, and the *assembly* hardware. The cladding for nuclear fuel assemblies is normally made of a *zirconium* alloy. However, about 1 percent of the spent nuclear fuel included in the Proposed Action is clad in stainless steel (Appendix A).

The sources of commercial spent nuclear fuel are the commercial nuclear powerplants throughout the United States. Figure 1-1 shows the locations of these sites. Appendix A, Section A.2.1, provides details on spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

Mixed-oxide fuel would be part of the commercial spent nuclear fuel inventory for the proposed repository. Section 1.2.4 includes a discussion of mixed-oxide fuel.

1.2.2.2 DOE Spent Nuclear Fuel

DOE spent nuclear fuel, like commercial spent nuclear fuel, has been withdrawn from a reactor following irradiation. Much of the DOE spent nuclear fuel is associated with past operations of reactors at the Hanford and Savannah River Sites that previously produced material for DOE's defense programs and research and development programs. These reactors are no longer operating. Smaller quantities of spent

nuclear fuel have resulted from experimental reactor operations and from research conducted by approximately 55 university- and government-owned test reactors (see Appendix A). DOE spent nuclear fuel also includes spent fuel from reactors on nuclear-powered naval vessels and naval reactor prototypes.

DOE stores most of its spent nuclear fuel in pools or dry storage facilities at three primary locations: the Hanford Site in Washington State, the Idaho National Engineering and Environmental Laboratory in Idaho, and the Savannah River Site in South Carolina. Some DOE spent nuclear fuel is currently stored at the Fort St. Vrain dry storage facility in Colorado (see Figure 1-1). Additional small quantities remain at other locations. With the exception of Fort St. Vrain, which will retain its spent nuclear fuel in dry storage until disposition, DOE plans to ship all of the spent nuclear fuel for which it is responsible from other sites to one of the three primary locations mentioned above for storage and preparation for ultimate disposition [discussed in DIRS 103205-DOE (1995, all)]. This EIS does not analyze consolidation of spent nuclear fuel at DOE sites (see DIRS 101802-DOE 1995, all). Appendix A, Section A.2.2, provides details on DOE spent nuclear fuel and discusses the amount currently stored and projected to be stored at each site.

1.2.3 HIGH-LEVEL RADIOACTIVE WASTE

DOE stores high-level radioactive waste in below-grade tanks at the Hanford Site, the Savannah River Site, the Idaho National Engineering and Environmental Laboratory, and the West Valley Demonstration Project in New York, a site presently owned by the New York State Energy Research and Development Authority (see Figure 1-1 for locations). High-level radioactive waste can be in a liquid, sludge, or saltcake form, and a solid immobilized glass form (see below). Liquid waste consists of water and organic compounds that contain dissolved salts. Sludge is a mixture of insoluble (that is, materials that will not dissolve in tank liquid) metallic salt compounds that precipitated and settled out of the solution after the waste became alkaline. Saltcake is primarily sodium and aluminum salt that crystallized from the solution following evaporation. High-level radioactive waste can also include other highly radioactive material that the Nuclear Regulatory Commission determines by rule to require permanent *isolation* (Nuclear Waste Policy Act definitions, Section 12), as well as immobilized plutonium waste forms. Appendix A, Section A.2.3, provides details on high-level radioactive waste and discusses the amount currently stored and projected to be stored at each site. Included in this total is immobilized high-level radioactive waste that will result from the electrometallurgical treatment of DOE sodium-bonded nuclear fuel at Argonne National Laboratory-West on the Idaho National Engineering and Environmental Laboratory site [*Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel* (65 *FR* 56565; September 19, 2000)].

The DOE process for preparing high-level radioactive waste for disposal starts with the transfer of the waste from storage tanks to a treatment facility. Treatment ordinarily includes separation of the waste into high-activity and low-activity fractions, followed by *vitrification* of the high-activity fraction. Vitrification involves adding materials to the waste and heating the mixture until it melts. The melted mixture is poured into canisters, where it cools into a solid glass or ceramic form that is very resistant to the leaching of radionuclides. The solidified, immobilized glass forms have been developed to keep the waste stable, confined, and isolated from the environment when inserted into disposal containers and disposed of in a monitored geologic repository. DOE will store the solidified high-level radioactive waste on the sites in *canisters* before eventual *shipment* to a repository. Figure 1-3 shows a representative vitrified high-level radioactive waste canister.

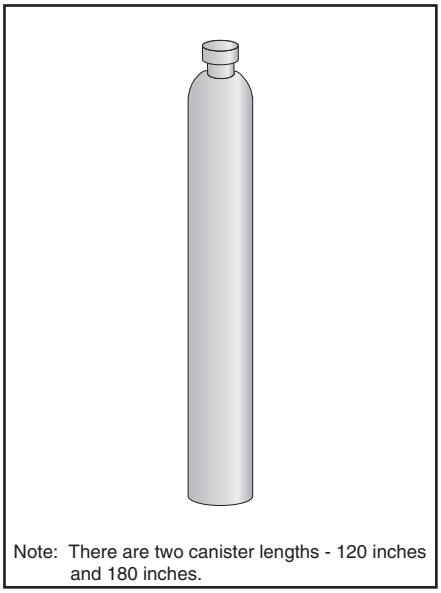


Figure 1-3. Vitrified high-level radioactive waste canister.

The low-activity fraction does not meet the definition of high-level radioactive waste. It is classified as low-level waste and is therefore considered generally acceptable for near-surface disposal under separate low-level waste disposal regulations.

DOE has begun to solidify and immobilize waste at the Savannah River Site, has completed most solidification and immobilization at West Valley, and plans to begin solidification and immobilization at Hanford. DOE has prepared a Draft EIS (DIRS 155100-DOE 1999, all) to help it determine the method it will use to prepare high-level radioactive waste at the Idaho National Engineering and Environmental Laboratory for disposal.

1.2.4 SURPLUS WEAPONS-USABLE PLUTONIUM

DOE has declared some weapons-usable plutonium to be surplus to national security needs (DIRS 118979-DOE 1999, p. 1-1). This material includes purified plutonium, nuclear weapons components, and materials and residues that could be processed to produce purified plutonium (Appendix A, Section A.2.4). DOE currently stores these plutonium-containing materials at various sites throughout the United States.

DOE could emplace surplus weapons-usable plutonium in the repository in two forms. One form would be an immobilized plutonium ceramic that DOE would dispose of as high-level radioactive waste. The second form would be mixed uranium and plutonium oxide fuel (called mixed-oxide fuel) assemblies that would be used for power production in commercial nuclear reactors and disposed of in the same manner as other commercial spent nuclear fuel. The analysis in this EIS assumed that approximately one-third of the surplus plutonium would be immobilized and approximately two-thirds would be mixed-oxide spent nuclear fuel (Appendix A). The actual split could include the immobilization of between one-third and all of the plutonium. Appendix A, Section A.2.4, contains details on sources, generation and storage status, and material characteristics of this surplus plutonium.

1.2.5 OTHER WASTE TYPES WITH HIGH RADIONUCLIDE CONTENT

The Nuclear Regulatory Commission classifies most low-level radioactive waste into Classes A, B, and C (10 CFR Part 61), which reflect increasing levels of radioactivity. *Greater-Than-Class-C* is the term for radioactive waste generated by commercial activities that exceeds Nuclear Regulatory Commission concentration limits for Class C waste, as specified in 10 CFR Part 61. The Nuclear Regulatory Commission has determined that shallow land burial of Greater-Than-Class-C low-level radioactive waste generally is not acceptable. *Special-Performance-Assessment-Required* waste is DOE-generated low-level radioactive waste with radioactive content higher than Class C shallow land disposal limits.

1.3 National Effort To Manage Spent Nuclear Fuel and High-Level Radioactive Waste

This section provides background information on the management of spent nuclear fuel and high-level radioactive waste, and describes the Nuclear Waste Policy Act of 1982 and its amendments.

1.3.1 BACKGROUND

In the late 1950s, active investigation began on the concept of mined geologic repositories for the disposal of spent nuclear fuel and high-level radioactive waste. In the 1970s, the United States reprocessed a small amount of commercial spent nuclear fuel to extract plutonium and studied the feasibility of expanded reprocessing. The plutonium would have been combined with uranium and used again as reactor fuel, substantially reducing the total amount of new enriched uranium required (DIRS 103414-NRC 1976, all). President Carter cancelled consideration of this approach, leaving disposal as the primary option for spent nuclear fuel.

In a February 12, 1980, message to Congress, President Carter stated that the safe disposal of radioactive materials generated by both defense and civilian nuclear activities is a national responsibility. In fulfillment of that responsibility, he announced a comprehensive program for the management of radioactive materials and adopted an interim planning strategy focusing on "the use of mined geologic repositories capable of accepting both waste from reprocessing and unreprocessed commercial spent fuel" (DIRS 104832-DOE 1980, p. 2.7). President Carter stated that he would reexamine this interim strategy and decide if changes were required after the completion of the environmental reviews required by the National Environmental Policy Act. As part of this reexamination, DOE issued the *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste* (DIRS 104832-DOE 1980, all). That EIS analyzed the environmental impacts that could occur if DOE developed and implemented various technologies for the management and disposal of spent nuclear fuel and high-level radioactive waste. It examined several alternatives, including mined geologic disposal, very deep hole disposal, disposal in a mined cavity that resulted from rock melting, island-based geologic disposal, subseabed disposal, ice sheet disposal, well injection disposal, transmutation, space disposal, and no action. The 1981 Record of Decision for that EIS announced the DOE decision to pursue the mined geologic disposal alternative for the disposition of spent nuclear fuel and high-level radioactive waste (46 *FR* 26677; May 14, 1981).

Internationally, permanent geologic disposal is the consensus choice of technology for the management of commercial spent nuclear fuel. The United States remains committed to disposal of commercial and DOE spent nuclear fuel, DOE high-level radioactive waste, and surplus weapons-usable plutonium in a geologic repository. This commitment assumes the acceptance and disposal in a U.S. repository of certain spent nuclear fuel that contains uranium enriched in the United States that has been used in foreign research reactors. This approach supports the U.S. advocacy for limiting international trade in weapons-usable nuclear materials and signals the U.S. commitment to a policy of nonproliferation of nuclear materials.

1.3.2 NUCLEAR WASTE POLICY ACT

In 1983, Congress enacted the Nuclear Waste Policy Act (Public Law 97-425; 96 Stat. 2201), which acknowledged the Federal Government's responsibility to provide permanent disposal of the nation's spent nuclear fuel and high-level radioactive waste, and established the Office of Civilian Radioactive Waste Management, which has the responsibility to carry out the evaluative, regulatory, developmental, and operational activities the Act assigns to the Secretary of Energy. The Nuclear Waste Policy Act began a process for selecting sites for technical study as potential geologic repository locations. In accordance with this process (shown in Figure 1-4), DOE identified nine candidate sites, the Secretary of Energy nominated five of the nine sites for further consideration, and DOE issued environmental assessments for the five sites in May 1986. DOE recommended three of the five sites (Deaf Smith County, the Hanford Site, and Yucca Mountain) for possible study as repository site candidates, and President Reagan approved the three as candidates. In addition, the Nuclear Waste Policy Act recognized a need to ensure that spent nuclear fuel and high-level radioactive waste now accumulating at commercial and DOE sites do not adversely affect public health and safety and the environment [NWPA, Section 111(a)(7)].

In 1987, Congress significantly amended the Nuclear Waste Policy Act. This Act, as amended (42 U.S.C. 10101 *et seq.*), which this EIS refers to as the NWPA, identified one of the three Presidentially approved candidate sites, Yucca Mountain, as the only site to be studied as a potential location for a geologic repository. Congress directed the Secretary of Energy to study the Yucca Mountain site and recommend whether the President should approve the site for development as a repository. Congress also required that a Final EIS accompany any Secretarial recommendation to approve the Yucca Mountain site to the President [NWPA, Section 114(a)(1)]. DOE has prepared this EIS to fulfill that requirement.

1.3.2.1 Requirement To Study and Evaluate the Site

In addition to the general responsibilities it establishes, the NWPA requires the Secretary of Energy specifically to characterize and evaluate the Yucca Mountain site for a geologic repository. The Act directs the Secretary of Energy to characterize only the Yucca Mountain site as a potential repository location and establishes a decisionmaking process to determine whether to designate Yucca Mountain as qualified for an application for repository construction authorization (NWPA, Sections 113, 114, 115, and 160).

Congress created the *Nuclear Waste Technical Review Board* as an independent organization to evaluate the technical and scientific validity of *site characterization* activities for the proposed repository and activities related to the packaging and transportation of spent nuclear fuel and high-level radioactive waste (NWPA, Section 503). The Nuclear Waste Technical Review Board must report findings, conclusions, and recommendations based on its evaluations to Congress and to the Secretary of Energy at least twice each year (NWPA, Section 508).

1.3.2.2 Elements of Site Evaluation

Sections 113, 114, and 115 of the NWPA contain specific and mostly sequential steps in the evaluation and decisionmaking process Congress has established for the Yucca Mountain site. The rest of this section and Section 1.3.2.3 describe that process.

The first steps in the evaluation and decisionmaking process for the Yucca Mountain site require the Secretary of Energy and, by extension, DOE, to gather data about Yucca Mountain and evaluate whether to recommend Yucca Mountain for approval as the site for a *license application* to the Nuclear Regulatory Commission for repository development. The Secretary's specific duties include:

- Undertake physical characterization of the Yucca Mountain site.
- Hold public hearings in the Yucca Mountain site *vicinity*.
- Prepare a description of the site, of spent nuclear fuel and high-level radioactive waste forms and packaging to be used, and of site safety.
- Decide whether to make a recommendation to the President on approval of the site for development as a repository.

Section 1.4.3.7 describes the elements that the Secretary of Energy must develop and consider in making a *site recommendation* to the President and in providing a statement of the basis for that recommendation.

The NWPA directs the Secretary of Energy to evaluate a *scenario* under which DOE would place an inventory of material in the proposed Yucca Mountain Repository. This EIS considers a repository inventory of 70,000 *metric tons of heavy metal (MTHM)* comprised of 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM of DOE spent nuclear fuel and high-level radioactive waste. This overall inventory includes surplus weapons-usable plutonium as spent mixed-oxide fuel and immobilized plutonium. Appendix A provides additional details of the inventory of materials.

Operating nuclear powerplants could generate approximately 105,000 MTHM of spent nuclear fuel through 2046. The total projected DOE inventory of materials includes 2,500 MTHM of spent nuclear fuel and approximately 22,280 canisters of high-level radioactive waste. Chapter 8 evaluates potential

consequences of using a repository at Yucca Mountain to dispose of all spent nuclear fuel and high-level radioactive waste that could be produced through 2046 for which DOE retains ultimate responsibility.

1.3.2.3 Site Qualification and Authorization Process

1.3.2.3.1 *U.S. Department of Energy Actions*

The Nuclear Waste Policy Act of 1982, subsequently amended, establishes a process leading to a decision by the Secretary of Energy on whether to recommend that the President approve Yucca Mountain for development of a geologic repository. As part of this process, the Secretary of Energy is to:

- Undertake site characterization activities at Yucca Mountain to provide information and data required to evaluate the site.

- Decide whether to recommend approval of the development of a geologic repository at Yucca Mountain to the President.

If the Secretary recommends the Yucca Mountain site to the President, the Nuclear Waste Policy Act, as amended in 1987 (the EIS refers to the amended Act as the NWPA), requires that a comprehensive statement of the basis for the recommendation, including the Final EIS, would accompany the recommendation. DOE has prepared this Final EIS so the Secretary can consider it, including the public input on the Draft EIS and on the Supplement to the Draft EIS, in making a decision on whether to recommend the site to the President.

The NWPA requires DOE to hold hearings in the vicinity of Yucca Mountain to provide the public with opportunities to comment on the Secretary's possible recommendation of the Yucca Mountain site to the President. If, after completing the hearings and site characterization activities, and after considering other information, the Secretary decided to recommend that the President approve the site, the Secretary would notify the Governor and Legislature of the State of Nevada accordingly. No sooner than 30 days after any such notification, the Secretary may submit the recommendation to the President to approve the site for development of a repository.

1.3.2.3.2 *Presidential Recommendation and Possible State and Congressional Action*

If, after any recommendation by the Secretary, the President considered the site qualified for an application to the Nuclear Regulatory Commission for a construction authorization, the President would submit a recommendation of the site to Congress. The Governor or Legislature of Nevada may disapprove the site designation by submitting a notice of disapproval to Congress within 60 days of the President's action. If neither the Governor nor the Legislature submit such a notice within the 60-day period, the site designation would become effective without further action by the President or Congress. If, however, the Governor or the Legislature submitted such a notice, the site would be disapproved unless, during the first 90 days of continuous session of Congress after the notice of disapproval, Congress passed a joint resolution of repository siting approval and the President signed it into law.

1.3.2.3.3 *Actions After Site Designation*

If a site designation became effective, the NWPA provides that the Secretary of Energy shall submit to the Nuclear Regulatory Commission an application for a construction authorization for a repository no later than 90 days after the date on which the site designation becomes effective. The NWPA requires the Commission to adopt DOE's Final EIS to the extent practicable as part of the Commission's decisionmaking on the License Application.

1.3.2.4 Environmental Protection and Approval Standards for the Yucca Mountain Site

Section 121 of the Nuclear Waste Policy Act of 1982 directed the U.S. Environmental Protection Agency to establish generally applicable standards to protect the general environment from *offsite* releases from radioactive materials in repositories and directed the Nuclear Regulatory Commission to issue technical requirements and criteria for such repositories. In 1992, Congress modified the rulemaking authorities of the Environmental Protection Agency and the Nuclear Regulatory Commission in relation to a possible repository at Yucca Mountain. Section 801(a) of the Energy Policy Act of 1992 directed the Environmental Protection Agency to retain the National Academy of Sciences to conduct a study and issue findings and recommendations on setting reasonable standards for protecting public health and safety in relation to a repository at Yucca Mountain. Section 801(a) also directs the Environmental Protection Agency to establish Yucca Mountain-specific standards based on and consistent with the Academy's findings and recommendations.

The National Academy of Sciences issued its findings and recommendations in a 1995 report (DIRS 100018-National Research Council 1995, all). The Environmental Protection Agency has issued standards for both storage and disposal of radioactive material at Yucca Mountain (40 CFR Part 197). The standards set health-based limits and *groundwater* protection limits for any radioactive releases from a repository at Yucca Mountain.

This EIS includes evaluation of the proposed Yucca Mountain repository's capability to satisfy the Environmental Protection Agency's regulations. Chapter 11 contains a more detailed discussion of these regulations and other requirements.

Section 801(b) of the Energy Policy Act directs the Nuclear Regulatory Commission to revise its general technical requirements and criteria for geologic repositories (10 CFR Part 60) to be consistent with the Environmental Protection Agency site-specific Yucca Mountain standards established at 40 CFR Part 197. The Nuclear Regulatory Commission has issued site-specific technical requirements and criteria (10 CFR Part 63). The Commission would use these requirements and criteria to evaluate an application to construct a repository at Yucca Mountain, to receive and possess spent nuclear fuel and high-level radioactive waste at such a repository, and to close and decommission such a repository.

The Nuclear Waste Policy Act of 1982 required the Secretary of Energy to issue general guidelines for use in recommending potential repository sites for detailed site characterization. DOE issued these guidelines in 1984 (10 CFR Part 960).

DOE has established site-specific regulations (10 CFR Part 963) that provide a portion of the basis for the evaluation of site suitability, as provided in the NWPA. The EIS provides current information on the proposed repository and presents an evaluation of the repository site, potential repository development, and anticipated repository performance measured against human health and other relevant technical criteria. DOE will comply with all applicable environmental and approval standards for the Yucca Mountain site.

1.4 Yucca Mountain Site and Proposed Repository

Spent nuclear fuel and high-level radioactive waste generate large amounts of *radiation* from the gradual decay of radioactive isotopes. These isotopes have the potential to cause severe human health impacts. In addition, the materials can generate heat from *radioactive decay* for periods lasting thousands of years. The Nuclear Waste Policy Act directs DOE to analyze and consider the disposal of spent nuclear fuel and high-level radioactive waste in a geologic repository.

1.4.1 YUCCA MOUNTAIN SITE

The site of the proposed Yucca Mountain Repository (see Figure 1-5) is on lands administered by the Federal Government in a remote area of the Mojave Desert in Nye County in southern Nevada, approximately 160 kilometers (100 miles) northwest of Las Vegas, Nevada. The area surrounding the site is sparsely populated and receives an average of about 170 millimeters (7 inches) of precipitation per year. Chapter 3, Section 3.1, provides detailed information on the environment at the site.

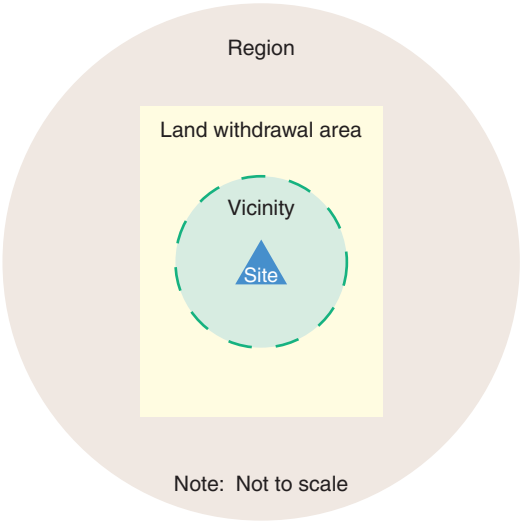
SITE-RELATED TERMS

Yucca Mountain site (the site): The area on which DOE has built or would build the majority of facilities or cause the majority of land disturbances related to the proposed repository.

Yucca Mountain vicinity: A general term used in nonspecific discussions about the area around the Yucca Mountain site. The EIS also uses terms such as area, proximity, etc., in a general context.

Land withdrawal area: An area of Federal property set aside for the exclusive use of a Federal agency. For the analyses in this EIS, DOE used an assumed land withdrawal area of 600 square kilometers, or 150,000 acres.

Region of influence (the region): A specialized term indicating a specific area of study for each of the resource areas that DOE assessed for the EIS analyses.



Controlled Area (as defined in 40 CFR Part 197) *(not shown on illustration):* The area surrounding the repository that is restricted to public access for the long term, as identified by passive institutional controls that DOE would install at closure. The controlled area could include as much as 300 square kilometers (about 120 square miles) surface and subsurface area. It would extend no more than 5 kilometers (3 miles) in any direction from the repository footprint except in the predominant direction of groundwater flow, where the controlled area would extend no farther south than 36 degrees, 40 minutes, 13.6661 seconds North latitude, the present latitude of the southwest corner of the Nevada Test Site [about 18 kilometers (11 miles)].

The Yucca Mountain site has several characteristics that would be expected to limit possible long-term impacts from the disposal of spent nuclear fuel and high-level radioactive waste. It is isolated from concentrations of human population and human activity and is likely to remain so. The very *arid* climate results in a relatively small volume of water that can move as groundwater in the mountain's unsaturated zone. The groundwater table sits substantially below the level at which DOE would locate a repository, providing additional separation between water sources and materials emplaced in waste packages. Maximizing the separation of water from the repository would minimize corrosion and would delay any mobilization and transport of radionuclides from the repository, as discussed in Chapter 5.

Groundwater from Yucca Mountain flows into a closed, sparsely populated hydrogeologic basin. A closed basin is one in which water introduced into the basin by rain cannot flow out the basin to any river or ocean. This closed basin provides a *natural barrier* to a general spread of radionuclides in the event that radioactive *contamination* reached the groundwater.

The *land withdrawal area* analyzed in the EIS includes about 600 square kilometers (230 square miles or 150,000 acres) of land currently under the control of DOE, the U.S. Department of Defense, and the U.S. Department of the Interior (see Figure 1-6). Approximately as many as 6.0 square kilometers (1,500 acres) comprising the repository site would be needed for development of surface repository facilities, with the remainder serving as a large buffer zone. If Yucca Mountain is recommended and approved for development as a repository, all or a portion of the land withdrawal area would have to be withdrawn permanently from public access to satisfy Nuclear Regulatory Commission licensing requirements at 10 CFR 60.121. If the land to be withdrawn included land that this EIS does not consider for withdrawal, DOE would perform additional analysis as required by the National Environmental Policy Act.

1.4.2 PROPOSED DISPOSAL APPROACH

The proposed monitored geologic repository at Yucca Mountain would be a large underground excavation with a network of *drifts* (tunnels) serving as the *emplacement* area for spent nuclear fuel and high-level radioactive waste. Rail, *legal-weight trucks,* or heavy-haul trucks would provide most of the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to the repository. Barges could move spent nuclear fuel from some sites to rail and truck transfer points. Shippers would transport the materials in Nuclear Regulatory Commission-approved shipping containers designed to transport radioactive materials with minimal risk to the public health and safety and to the environment. (Chapter 6 discusses potential transportation systems.) Figure 1-7 shows the concept of temporary storage of spent nuclear fuel and high-level radioactive waste at storage sites, transporting these materials to the proposed repository, and disposing of the materials in an emplacement area.

At the repository, the material would be loaded in disposal containers. The filled disposal containers would be sealed, thereby becoming waste packages. The waste packages would be moved underground by rail. Remote-controlled handling vehicles would place the waste packages in emplacement drifts. The waste packages, which would be designed to remain intact for thousands of years (at a minimum), would be part of an *engineered barrier system* inside the mountain that would isolate spent nuclear fuel and high-level radioactive waste from the environment. The engineered barrier system, together with the geologic and hydrologic properties of the Yucca Mountain site, would ensure that a potential release of radioactive material after repository *closure* would meet applicable performance standards to contain and isolate the waste for 10,000 years or more. Chapter 5 provides detailed discussions of the *natural system* and of waste packages. Chapter 2 describes the Proposed Action at Yucca Mountain in additional detail, including the transportation activities required to move the spent nuclear fuel and high-level radioactive waste to the site.

Under the NWPA, the proposed repository, if authorized, would be a facility for the permanent disposal of 70,000 MTHM of spent nuclear fuel and high-level radioactive waste. The Nuclear Waste Policy Act requires the Nuclear Regulatory Commission to include in the authorization a prohibition against the emplacement of more than 70,000 MTHM in the first repository until a second repository is in operation [Nuclear Waste Policy Act, Section 114(d)]. DOE has allocated 63,000 MTHM of commercial spent nuclear fuel and 7,000 MTHM equivalent of DOE spent nuclear fuel and high-level radioactive waste to the proposed repository at Yucca Mountain. The Proposed Action that this EIS evaluates, therefore, includes the transportation of spent nuclear fuel and high-level radioactive waste from the present storage sites to Yucca Mountain and the emplacement of as much as 70,000 MTHM of spent nuclear fuel and high-level radioactive waste in the proposed repository. Chapter 8 of this EIS analyzes cumulative impacts from the disposal at Yucca Mountain of all spent nuclear fuel and high-level radioactive waste projected to be produced through 2046 for which DOE will retain ultimate responsibility. Chapter 8 also considers the disposal of *Greater-Than-Class-C waste* and *Special-Performance-Assessment-Required waste* at Yucca Mountain.

1.4.3 DOE ACTIONS TO EVALUATE THE YUCCA MOUNTAIN SITE

DOE has performed site characterization activities at Yucca Mountain for almost two decades, and has issued several documents related to those studies, in addition to the Draft EIS, Supplement to the Draft EIS, and this Final EIS, that would form part of the basis for a potential Site Recommendation. The following sections address these activities and reports, and provide a brief description of the No-Action Alternative.

1.4.3.1 Site Characterization Activities

In accordance with the NWPA [Section 113(b)], the DOE Office of Civilian Radioactive Waste Management prepared a Site Characterization Plan for the Yucca Mountain site (DIRS 100282-DOE 1988, all). DOE has had a program of investigations and evaluations to assess the suitability of the Yucca Mountain site as a potential geologic repository and to provide information for this EIS. The program consists of scientific, engineering, and technical studies and activities.

Examples of activities, investigations, and evaluations associated with site characterization include the following:

- Construction of an *Exploratory Studies Facility,* including the North and South *Portal* Ramps (openings into the mountain)
- Excavation of underground tunnels and rooms in the Exploratory Studies Facility for scientific and engineering studies, testing, and experiments
- Investigations of such topics as *hydrology,* including groundwater characteristics; general site geology; and specific geologic issues such as erosion, *seismicity,* and volcanic activity
- Field monitoring, including *air quality,* meteorological, radiological, and water resources monitoring
- Cultural resources studies, including Native American interests
- Terrestrial ecosystem studies

1.4.3.2 Viability Assessment

In the *Viability Assessment of a Repository at Yucca Mountain (Viability Assessment)* (DIRS 101779-DOE 1998, all), DOE evaluated a preliminary design based on scenarios that focused on the amount of spent nuclear fuel (and associated thermal output) that DOE would emplace per unit area of the repository. This concept was called *areal mass loading*. For analytical purposes, areal mass loading was represented in the Viability Assessment and in the Draft EIS by a high thermal load scenario, an intermediate thermal load scenario, and a low thermal load scenario. DOE selected these scenarios to represent the range of foreseeable design alternatives, and to ensure that it considered the associated range of potential environmental impacts. The Viability Assessment included the following:

- Preliminary design scenarios for critical elements of the repository and *waste package*
- A *total system performance assessment,* based on the design concept and the scientific data and analyses available by 1998, that described the probable behavior of the repository in the Yucca Mountain geologic setting

- A plan and cost estimate for the remaining work required to complete and submit a License Application to the Nuclear Regulatory Commission

- An estimate of the costs to construct and operate the repository in accordance with the design concept

The Draft EIS summarized results from the Viability Assessment, where applicable. DOE did not intend the scenarios studied in the Viability Assessment to place limits on choices among alternative designs. DOE expected the repository design to continue to evolve in response to ongoing site characterization and design-related evaluations.

1.4.3.3 Yucca Mountain Science and Engineering Report

Since the publication of the Draft EIS, DOE has continued to evaluate design features and operating modes that would improve long-term repository performance, reduce uncertainties in performance, and improve operational safety and efficiency. DOE documented the design evolution process in the *Yucca Mountain Science and Engineering Report: Technical Information Supporting Site Recommendation Consideration* (Science and Engineering Report; DIRS 153849-DOE 2001, all). The result of the process was the Science and Engineering Report Flexible Design (which this Final EIS calls the *flexible design*). DOE evaluated the flexible design in a Supplement to the Draft EIS, released for public review and comment in May 2001.

The Yucca Mountain Science and Engineering Report describes:

- Waste forms to be disposed of

- Results of scientific and engineering studies completed to date

- The flexible design for the repository (preliminary engineering specifications)

- A range of repository operating modes under the flexible design

- Waste package designs (preliminary engineering specifications)

- Results of recent assessments of the long-term performance of the potential repository (Total System Performance Assessment)

The Science and Engineering Report documents information that the Secretary of Energy will use to determine whether to recommend approval of the Yucca Mountain site to the President, including scientific investigations, site characterization studies, and evaluation of how conditions might evolve over time. In the flexible design, the basic elements of the proposed action, to construct, operate and monitor, and eventually close a geologic repository at Yucca Mountain remain unchanged. The flexible design provides the capability to operate the repository in a range of operating modes to affect conditions of temperature and associated humidity. The *higher-temperature repository operating mode* would raise at least portions of the rock walls between the emplacement drifts to a maximum temperature above 96ºC (205ºF), which is the boiling point of water at the repository elevation. The *lower-temperature operating mode* incorporates a range of scenarios that include conditions under which the surface temperature of emplaced waste packages would not exceed 85ºC (185ºF).

The Science and Engineering Report was issued in May 2001 for public comment. At the time of preparation of this Final EIS, DOE was revising this report to address these comments.

1.4.3.4 Preliminary Site Suitability Evaluation

Following the Science and Engineering Report, DOE released the *Yucca Mountain Preliminary Site Suitability Evaluation* (DIRS 155734-DOE 2001, all). The Preliminary Site Suitability Evaluation presents currently available information to support a preliminary evaluation of the suitability of the Yucca Mountain site for a monitored geologic repository and describes preliminary results of DOE's evaluation of whether the site is suitable for such a repository.

The Preliminary Site Suitability Evaluation compares the preliminary results of DOE's evaluation with DOE's proposed (since promulgated) site suitability guidelines. These preliminary results indicated that a potential repository at Yucca Mountain would likely meet Environmental Protection Agency radiation protection standards and proposed (since promulgated) Nuclear Regulatory Commission regulations for protecting people and the environment.

The purpose of the information provided in the Preliminary Site Suitability Evaluation is to aid the public in its review and comments on this aspect of the bases for the Secretary of Energy's consideration of a possible Site Recommendation.

The Preliminary Site Suitability Evaluation was issued in August 2001 for public comment. At the time of preparation of this Final EIS, DOE was revising this document to address these comments.

1.4.3.5 Supplemental Science and Performance Analyses

DOE has also issued the *Supplemental Science and Performance Analyses* (DIRS 155950-BSC 2001, all; DIRS 154659-BSC 2001, all). This document describes supplemental analyses that have been conducted on long-term repository performance, incorporating those analyses into a supplemental Total Systems Performance Analysis (TSPA). The *Supplemental Science and Performance Analyses* first describes technical work conducted in each process model area and modifications to the Total System Performance Assessment model, and then describes the performance assessment analyses and results based on the technical work and model modification.

1.4.3.6 Total System Performance Assessment–Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain–Input to Final Environmental Impact Statement and Site Suitability Evaluation

DOE has issued the *Total System Performance Assessment – Analyses for Disposal of Commercial and DOE Waste Inventories at Yucca Mountain – Input to Final Environmental Impact Statement and Site Suitability Evaluation* (DIRS 157307-BSC 2001, all). This assessment integrates information from all previous long-term performance models and provides further modification to the *Supplemental Science and Performance Analyses.* The results from this assessment, which are the most current available at the time of Final EIS production, directly support the long-term performance evaluation in the Final EIS.

1.4.3.7 Site Recommendation

Section 114(a) of the Nuclear Waste Policy Act requires that any recommendation by the Secretary of Energy be based on the record of information developed during site characterization and be submitted to the President together with a comprehensive statement of the basis of that recommendation. The recommendation is to be supported by:

- A description of the proposed repository, including preliminary engineering specifications for the facility

- A description of the *waste form* or packaging proposed for use at the repository, and an explanation of the relationship between such waste form or packaging and the geologic medium of the site
- A discussion of data obtained in site characterization activities that relate to the safety of the site
- A Final EIS prepared for the Yucca Mountain site accompanied by comments from the Department of the Interior, the Council on Environmental Quality, the Environmental Protection Agency, and the Nuclear Regulatory Commission
- The preliminary comments of the Nuclear Regulatory Commission on the extent to which the waste form proposal and the at-depth site characterization analysis seem to be sufficient for inclusion in a License Application
- The views and comments of the governor and legislature of any state and of the governing bodies of affected Native American tribes, together with responses from the Secretary of Energy to such views
- Any impact report submitted under Section 116(c)(2)(B) of the NWPA by the State of Nevada
- Other information the Secretary considers appropriate

1.4.3.8 No-Action Alternative

Under the No-Action Alternative, DOE would end site characterization activities at Yucca Mountain and begin site *decommissioning* and reclamation. The commercial utilities and DOE would continue to store spent nuclear fuel and high-level radioactive waste. For purposes of analysis, the No-Action Alternative assumes that those sites would treat and package the materials, as necessary, in a condition ready for shipment to a repository. The potential environmental impacts from two No-Action scenarios, described below, serve as a basis for comparison to the potential environmental impacts of the Proposed Action.

- Scenario 1 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites under *institutional control* for at least 10,000 years.
- Scenario 2 assumes that spent nuclear fuel and high-level radioactive waste would remain at the commercial and DOE sites in perpetuity, but under institutional control for only about 100 years. This scenario assumes no effective institutional control of the stored spent nuclear fuel and high-level radioactive waste after 100 years.

INSTITUTIONAL CONTROL

Monitoring and maintenance of storage facilities to ensure that radiological releases to the environment and radiation doses to workers and the public remain within Federal limits and DOE Order requirements.

DOE recognizes that neither scenario would be likely if there was a decision not to develop a repository at Yucca Mountain; however, they are part of the EIS analysis to provide a basis for comparison to the Proposed Action. There are a number of possibilities that DOE could pursue, including continued storage of the material at its current locations or at one or more centralized location(s); the study and selection of another location for a deep geologic repository; development of new technologies; or reconsideration of alternatives to deep geologic disposal. One such centralized storage possibility, the proposed Private Fuel Storage Facility for commercial spent nuclear fuel in Utah, is currently in the Nuclear Regulatory Commission licensing process. The Commission issued a Final EIS in January 2002, however, that document was unavailable for use during the preparation of this Final EIS. The Commission has yet to issue a decision on whether to grant a license.